भारतीय मानक
Indian Standard

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चट्टान के विरूपण के मापांक के लिये एक अक्षीय जैकिंग परीक्षण — रीति संहिता

(दूसरा पुनरीक्षण)

Uniaxial Jacking Test for Deformation Modulus of Rock Mass — Code of Practice

(Second Revision)

ICS 93.020

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली – 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.gov.in www.standardsbis.in

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Rock Mechanics Sectional Committee, CED 48

FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

In general rock mass is heterogeneous, anisotropic and discontinuous, and its mechanical behaviour is governed by the existence and orientation of discontinuities, such as, bedding planes, joints, fracture zones, and the degree of weathering, etc. These discontinuities may be clean or filled with fine grained material, rough or smooth, and may be continuous or discontinuous. As such, the mechanical properties of rock mass differ greatly from the laboratory test results carried out on small samples of intact rock. The parameters actually needed in design are the *in*-situ properties of rock mass and not that of intact rock. In designing and constructing engineering structures over or inside the rock mass, the main parameters of importance are its deformability, shear and other strength characteristics. Out of these three parameters, the dispersion in the test results of shear characteristics and the strength of a particular rock mass has been observed to be small as compared to the deformability values of the same. The deformation characteristics of *in-situ* rock is one such property which needs utmost care in its evaluation. It depends largely on the adopted technique of testing, the loaded area, the loading system, and the methodology by which the results are interpreted.

Modulus of deformation is an essential parameter for the design of tunnels, underground chambers, mines and dam foundations. The deformability of the rock mass will govern the strain conditions that develop around an excavation during its initial changes. When designing a structure in or on a rock mass, it is important to know the deformability characteristics of the same for following two reasons:

a) To assess expected displacements during excavation and relate these to subsequent monitoring to check stability; and
b) To permit the correct design of any rock support measures that must be able to accommodate the expected deformation without failure.

Deformation modulus of rock mass may be determined by bore hole jack test, uniaxial jacking test, pressure chamber test and radial jacking test, etc. In case of uniaxial jacking tests, the loading of a jointed rock mass has to be arranged in the direction conforming to design requirement. Alternatively, it may be determined in two perpendicular directions and the value in required direction computed according to normal practice.

The results of bore hole jack tests may be used only as an index of rock mass deformability and there is strong dependence on jack-rock interaction and moreover the corrections are uncertain. Flat jack tests are severely limited by access problems, and only shallow rock in a disturbed state can be used to measure deformability adjacent to exposed surface and the results do not provide the deformability of the rock mass. Radial jacking tests and pressure chamber tests are better as they cause deformation of much larger volume of rock mass around the drift/tunnel and hence are most representative. But these tests are difficult to conduct and are very expensive.

The main disadvantage of all the above methods except in the bore hole jack tests, is that the results are influenced by blast damage and stress relief and therefore controlled excavation methods are required. The bore hole jack tests have the advantage that large number of locations can be tested rapidly and hence the test is sometimes used without recognition of its limitations. On the other hand Uniaxial Jacking tests are easy to conduct, relatively cheaper, and are much simpler. This test determines how *in*-situ rock reacts to controlled loading and unloading cycles and provide data on deformation moduli, creep and rebound. The modulus of deformation of rock mass is lower than the elastic modulus of intact rock material as determined in the laboratory.

This standard was originally published in 1974 and subsequently revised in 1993. The first revision provided a general discussion of the uniaxial jacking test procedures. It updated the information and explained in more details the procedures utilized to accomplish the test. It also gave recommended interpretation of the modulus of deformation for use in technical analysis.

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Indian Standard

UNIAXIAL JACKING TEST FOR DEFORMATION MODULUS OF ROCK MASS — CODE OF PRACTICE

(Second Revision)

1 SCOPE

1.1 This standard covers the method for determination of modulus of deformation of rock mass by uniaxial loading technique in which pressures are exerted on two parallel flat rock faces on the two opposite sides of a section of a drift, gallery or tunnel by means of hydraulic jacks. The applied pressure and the resulting displacements are used for the determination of the modulus of deformation by the help of the appropriate elastic theory. The modulus of deformation is not a constant parameter, its value depends upon the stress level also. The choice of the design value for the *in-situ* modulus of deformation or elastic modulus thus becomes a matter of engineering judgement.

1.2 The creep characteristics of the rock mass may be computed from the graphs of displacement *versus* time.

1.3 The effects of anisotropy may be determined by applying the load in any desired direction. However, in jointed rocks, the test shall be conducted in the direction conforming to design requirement.

2 SELECTION OF TEST SITE

2.1 Prior to selecting a test site location, all available surface and sub-surface geological data of the exploratory drift shall be complied and analysed by the geologist. A three dimensional portrayal of these data shall also be prepared in plotted form.

2.2 After detailed exploration, sufficient geological mapping, and reviewing all available information in the exploratory drifts, the zone of the influence of structure (dam, tunnel, under-ground openings, etc), may be divided into different lithological units and then sub-divided further into various structural zones. In each of these similar zones, a minimum of about four tests may be carried out. If large variations are found in the obtained results, additional confirmatory tests should be carried out to be able to choose design values for each zone.

2.3 The test site shall be selected such that the geology at the test location is representative of the geology of the area loaded by the structure to be built.

2.4 Testing in drifts, tunnels or any other under-ground openings is preferred for convenience. In the absence of such facility, the test may be located close to the sides of open excavations for foundation or abutments.

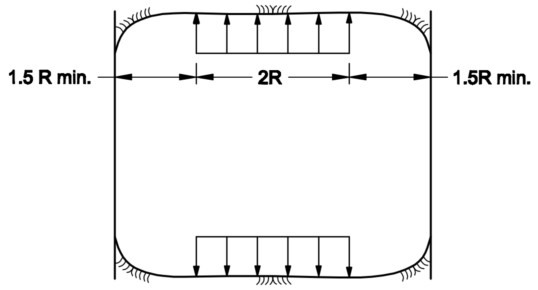
2.5 After selecting the test site, the geologist shall prepare a three dimensional map showing the micro geology of the *in-situ* rock mass falling under the influence of test. The following information pertaining to the test location may preferably be collected and jointly recorded by a team of geologists and engineers:

a) Rock quality designation (RQD);
b) Point load strength index of the rock material;
c) Number of joint sets, their dip and strike;
d) Spacing and condition of joints;
e) Ground water condition, dry/damp/wet/ dripping/ lowing;
f) Rock mass rating (RMR) and rock mass quality (Q);
g) Modulus of elasticity of rock material;
h) Special features that is, presence of shear or fault zones, etc;
j) Method adopted for excavation of the drift that is by controlled blasting; hand chiselled or by any other means; and
k) Description of damages due to blasting.

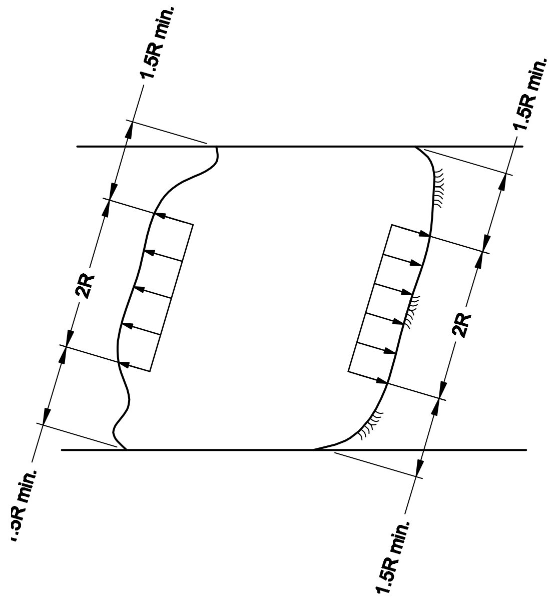
3 PREPARATION OF TEST SITE

3.1 The size of the drift or gallery in which tests arc to be carried out shall be kept as small as required for testing, so as to reduce the number of packing plates or the size of the intervening truss placed across the tunnel. The size of the exploratory drift shall be such that the distance between the loaded area and a restraining tunnel surface shall be at least equal to the radius of the loaded area (R) so that any restraint would not affect the calculated moduli significantly, as shown in Fig. 1. In the absence of the exploratory drift, these tests can be conducted in open area. Excavation of trench can also be considered for testing on fresh rock.

The standard size of the opening convenient for the test being about 1.8 m wide and 2.1 m height. The excavation of the drift shall be made in such a manner as to cause minimum disturbance of rock to be tested. Blasting shall not be allowed during final preparation of the test site.



1A SITE CONDITION A (IDEALIZED)



1B SITE CONDITION B (IDEALIZED)

Fig. 1 Distance Between the Loaded Area and the Restraining Surface

3.2 After site selection, the area selected for testing shall he carefully prepared as quickly as possible, preferably within 15 days of the test site selection. In case of rocks being susceptible to loosening and weathering, tests should be conducted within thirty days of excavation of drift to obtain properties of fresh rock mass.

3.2.1 All loose rock material shall be removed by using chipping hammers and drills. The final trimming of rock to provide two parallel, concentric and smooth rock faces, about 50 mm larger than the test plate shall be done by means of chisel and hammer. The areas shall be finally ground smooth. There shall be an understanding between the field engineers and test engineers on the importance of careful treatment of rock during all excavation phases. Both ends of prepared rock surface should be concentric and levelled for uniform load distribution.

4 TEST SET-UP

4.1 The test set up depends upon various conditions of testing, that is, whether the test is carried out in a small drift or in a wider tunnel or in an open trench, whether the test is carried out in a vertical or horizontal or inclined direction, and whether the resulting deformations are measured with respect to the bearing plate, or outside the loaded area or inside the rock mass along the centre line of the loaded surface.

4.2 For some typical test set-ups Figs. 2, 3 and 4 may be referred.

4.2.1 Figure 2 depicts the arrangement for vertical test set up in small drifts and galleries where the deformations are measured with respect to the bearing plates.

4.2.2 Figure 3 shows a similar test set-up in a wider tunnel. However, for inclined tests, suitable supporting structures may be designed.

4.2.3 Figure 4 indicates an inclined test set-up in a small drift where the deformations are measured inside the rock mass along the centre line of the loaded area.

4.3 Set-Up for Narrow Drifts and Galleries

4.3.1 The minimum size of the steel bearing plate shall be 25 mm thick and 600 mm diameter. The size of the plate to be used at a given test site shall however not be less than 3 to 4 times the average spacing of joint or crack pattern subject to the limitations of the testing capacity available. Two such circular or square rigid steel plates shall be placed in contact with the rock surface with an intervening layer of concrete or any other materials equivalent to modulus of rock mass. The maximum thickness of the intervening layer shall be about 5 cm. The test location shall be saturated with water to simulate seepage at site. The concrete or any other material shall be allowed to cure sufficiently to obtain adequate strength prior to commencement of test. The space between the steel plate and the intervening layer and between the steel plate and the packing plate may be filled with teflon sheet of sufficient thickness in order to have a uniform transfer of load.

4.3.2 The loading apparatus shall be such that it is capable of applying simultaneous uniform pressures to two test areas on the opposite rock faces prepared. A calibrated hydraulic jack of capacity commensurate with the required stress or a minimum of 200 T and capable of maintaining the desired pressure to within 2 percent of a selected value throughout the duration of the test shall be used for load application. The hydraulic pump system with necessary fittings, valves, gauges

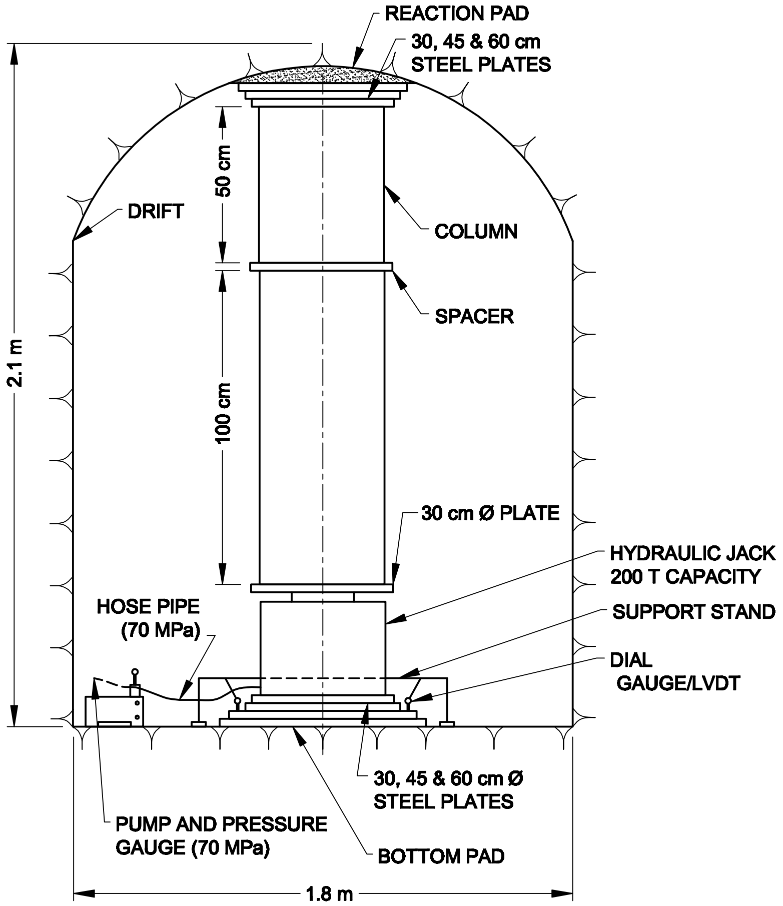


FIG. 2 SETUP FOR UNIAXIAL JACKING TEST IN VERTICAL DIRECTION WITH STIFF PLATE

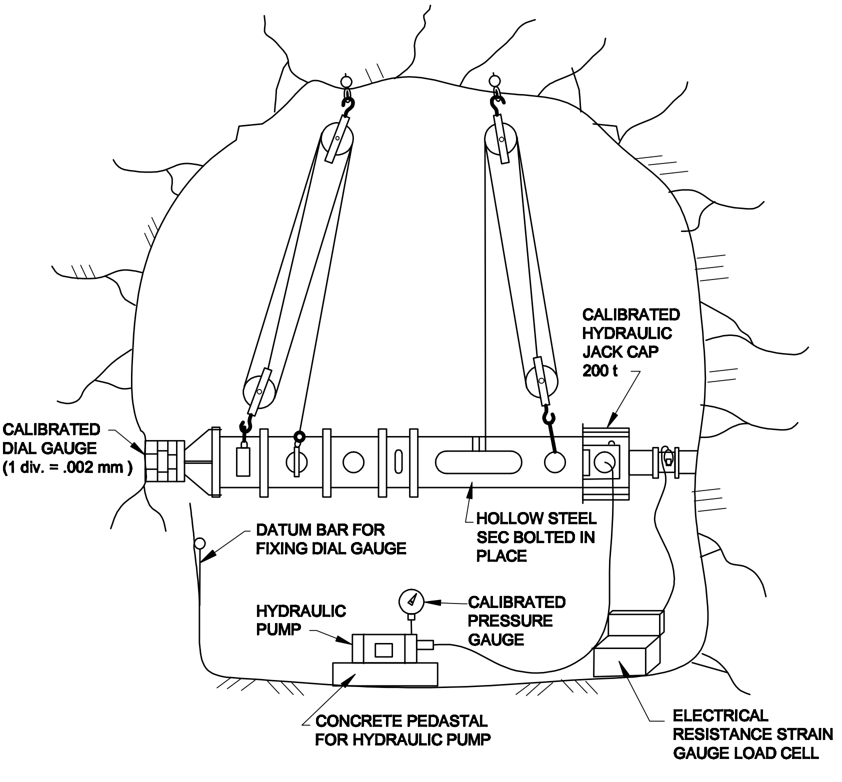
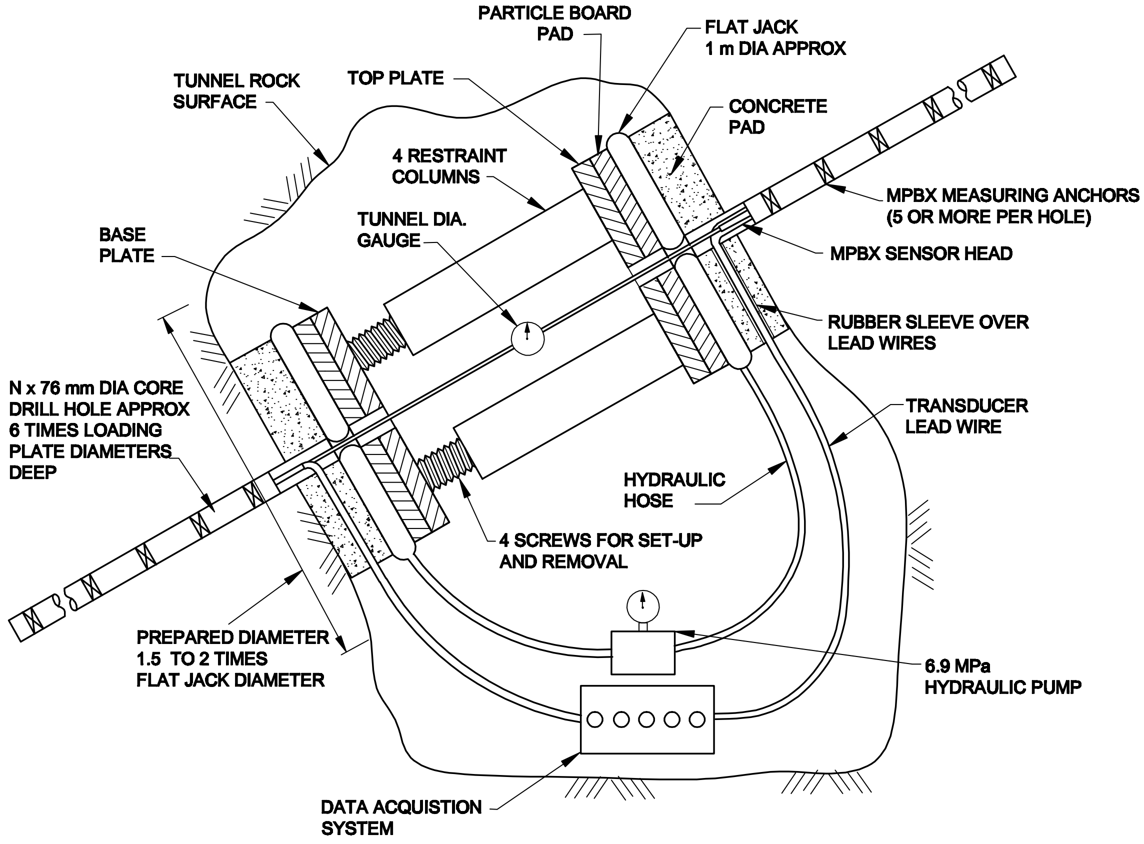


FIG. 3 SET UP FOR UNIAXIAL JACKING EQUIPMENT FOR WIDER TUNNEL LOCATIONS


PARTICLE BOARD PAD
FLAT JACK 1 m DIA APPROX
TUNNEL ROCK SURFACE
TOP PLATE
CONCRETE PAD
4 RESTRAINT COLUMNS
MPBX MEASURING ANCHORS (5 OR MORE PER HOLE)
TUNNEL DIA. GAUGE
BASE PLATE
MPBX SENSOR HEAD
RUBBER SLEEVE OVER LEAD WIRES
N x 76 mm DIA CORE DRILL HOLE APPROX 6 TIMES LOADING PLATE DIAMETERS DEEP
TRANSDUCER LEAD WIRE
HYDRAULIC HOSE
4 SCREWS FOR SET-UP AND REMOVAL
PREPARED DIAMETER 1.5 TO 2 TIMES FLAT JACK DIAMETER
6.9 MPa HYDRAULIC PUMP
DATA ACQUISTION SYSTEM

NOTE - TIMBER PLATFORM FOR SUPPORT DURING ERECTION NOT SHOWN

FIG. 4 SET-UP FOR UNIAXIAL JACKING EQUIPMENT IN DRAFTS WHERE DEFORMATIONS ARE MEASURED INSIDE THE ROCK MASS

and hoses shall also have sufficient pressure capacity and volume for applying the desired loads. Generally it shall be preferred to use two stage pump to cover lower and higher pressure ranges. steel packing plates of sufficient thickness or material of equivalent rigidity, shall be placed in between the hydraulic jack and the steel plates in contact with the rock faces. Two of the packing plates should be of special design and should be provided with four equally spaced holes through which micrometer dial gauges are attached to measure independently the displacement or deformation of rock at the top and the bottom. The final gap, if any, between the plates should be closed by moving the plunger forward by operating the pump. A small initial load, about 0.5 kg/cm^2 should be applied to remain for a minimum period of 24 h to allow for the setting of cement mortar or 6 h for setting of plaster of paris before starting the test. Before applying the initial load it should be ensured that all the packing plates are concentric with the plunger of the jack, and in turn concentric with the plates.

4.3.3 The dial gauges or linear variable differential transformers (LVDT) capable of reading up to 0.002 mm with a minimum travel of 25 mm should be set up to give deformations of the four corners of each bearing plate. By moving the brass screws, the gauges should be adjusted to show initial reading nearly three fourths of the entire range of travel of the gauge.

Deformations of the two plates should be measured independently as the type and condition of the rock may be different at the two faces because of loosening or stress relief in the rock mass in the roof or sides of the drift.

The dial gauge or LVDT should be supported on beam connecting two rigid stands located outside zone of influence of tests. The stand should be located at distance of 1 to 2 times the diameter of test plate.

4.4 Set-Up for Wider Tunnel Locations

The setup is shown in Fig. 3 and it is suitable for horizontal loading for locations in wider tunnels. In this case also the deflections of each face are measured separately with respect to independent datum located at a distance of about 3 to 4 times the size of the plate, along the axis of the tunnel. The deflection is recorded by the help of four dial gauges at one face.

4.5 Set-Up for Drifts where the Deformations are Measured inside the Rock Mass

The typical set up has been shown in Fig. 4. In this case, 600 mm to 1 000 mm diameter flat jacks shall be used in place of bearing plates at the two ends. In the set-up, the deformations shall be measured at the centre of the loaded area both at the surface and at different depths using multiple point extensometers located in central NX-76 mm diameter bore hole and with reference to a datum fixed at a depth of 6 times plate diameters.

4.6 Set-Up for Open Foundation/Trench

The typical set-up for conducting the tests in open trench is shown in Fig. 5. Similar arrangement can be adopted for tests in open area. Normal load can be applied by taking reaction from kentledge, anchored truss or any dead weight arrangements. Set up for deformation measurements inside drift and open surface is similar.

5 TEST PROCEDURE

5.1 As far as possible, preference shall be given to the testing with flexible loading arrangement and deformation measurement inside rock mass as shown in Fig. 4. However, if it is not possible to deploy this test set up, the testing with stiff loading arrangement and deformation measurement on surface as shown in Figs. 2 or 3 may be used.

5.2 After all components of the test set are installed, they shall be checked jointly by the field and test engineers. A final check of all mechanical, hydraulic and electronic components (if any) shall be made after the concrete pads are placed and again before the first load increment is applied.

5.3 Test shall be conducted continually on a 24 h a day basis utilising load ranges and increments compatible with the particular design considerations.

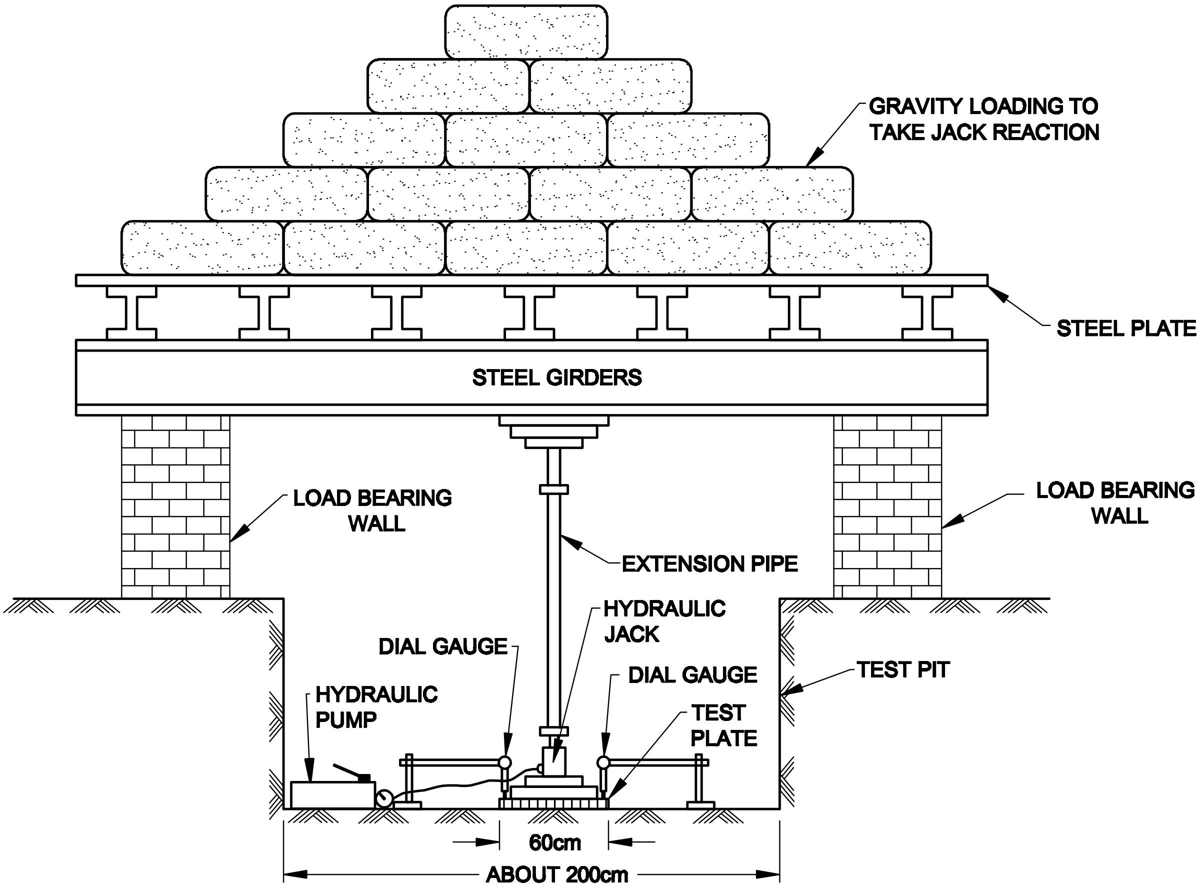


Fig. 5 Set-Up for Uniaxial Testing in Open Foundation/Trench

5.4 The test shall be started after allowing sufficient time for curing of concrete pads in both surfaces. The initial load applied shall be reduced to bare minimum to hold the steel plates in position, say about 0.5 kg/cm.

5.5 Rock deformation shall be recorded at sufficient intervals and a minimum of six readings during the first hour of each load increment or decrement is recommended.

5.6 The maximum load at which the test is to be conducted shall correspond to 1.2 to 1.5 time the anticipated maximum stress liable to be developed because of the proposed structure. Care shall be taken to check that the rock mass is not stressed beyond its strength. The test shall be conducted in a total number of five cycles. Each cycle shall consist of 20 percent of maximum test stress. In each cycle of loading, the load increments may be at least one fifth to one tenth of the test load involved in each cycle. The unloading, should be done similar to loading steps. The test being a cyclic loading test, the load shall be brought down to the initial load applied to hold the plates in position, each time before reloading for another cycle. Deflection given by dial gauges and the corresponding load (or stress) shall be noted. The dial gauge readings should be continued till it is less than one division over a period of 30 min. Besides, the duration of each pressure increment may be determined by the creep characteristics of the rock mass. Plot of deformation *versus* time shall be prepared by conducting separate test. This plot is useful for studying the creep characteristics of the rock. In uniaxial jacking test the duration of load increment for each cycle shall be fixed up to 1 h in general and may be increased up to 5 h depending upon the rock mass condition. However, experience of the test party and critical examination of observations during the first pressure increment can be used to modify time requirements for successive increments. The results shall be plotted in the stress deformation diagram which forms the basis of interpretation for analysing the behaviour of the rock mass under imposed load and for determining the values of the deformation and elastic moduli, and the magnitude of irreversible deformations.

5.7 After the test is completed, the installation procedure is reversed and the entire set up is retrieved for subsequent use. The concrete pads shall be removed so as not to create a safety hazard by having them fallen by the action of gravity at some later date.

5.8 The data observed during the test may be plotted to give deformation *versus* stress, time and depth below the surface curves (*see* Figs. 6, 7 and 8) to calculate moduli of deformation/ elasticity at various stress levels, creep factors and the variation of moduli with respect to depth.

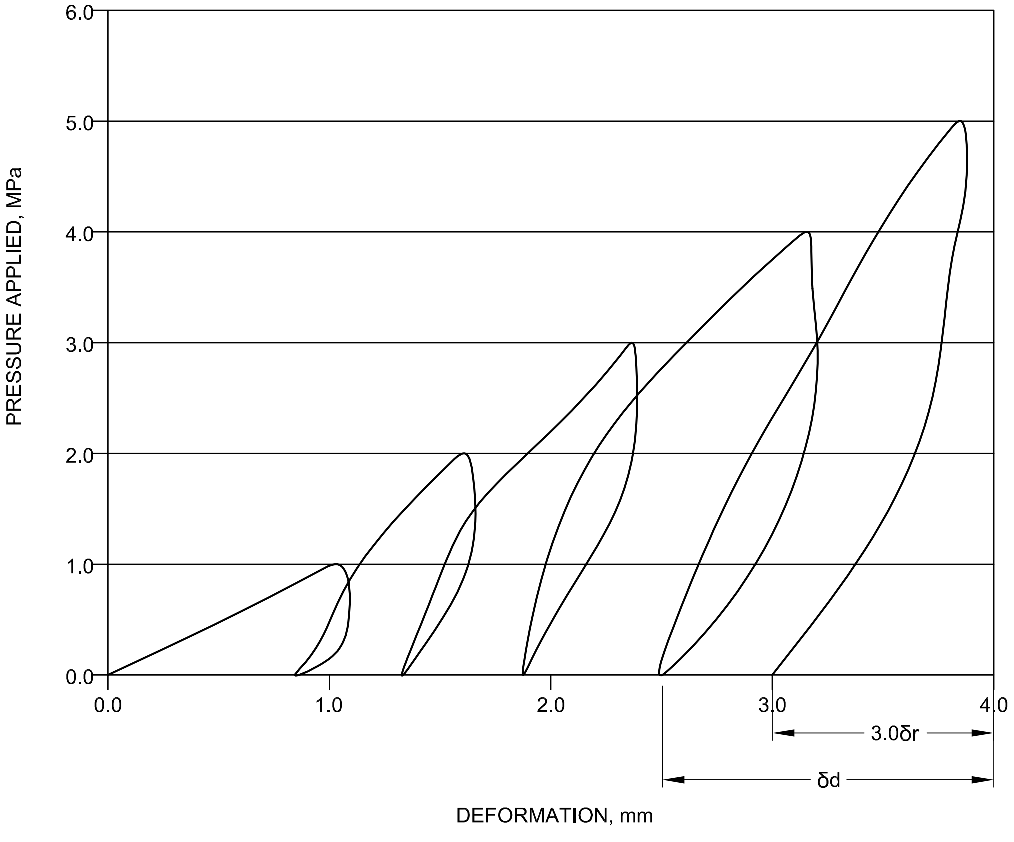


FIG. 6 DEFORMATION *VERSUS* PRESSURE APPLIED

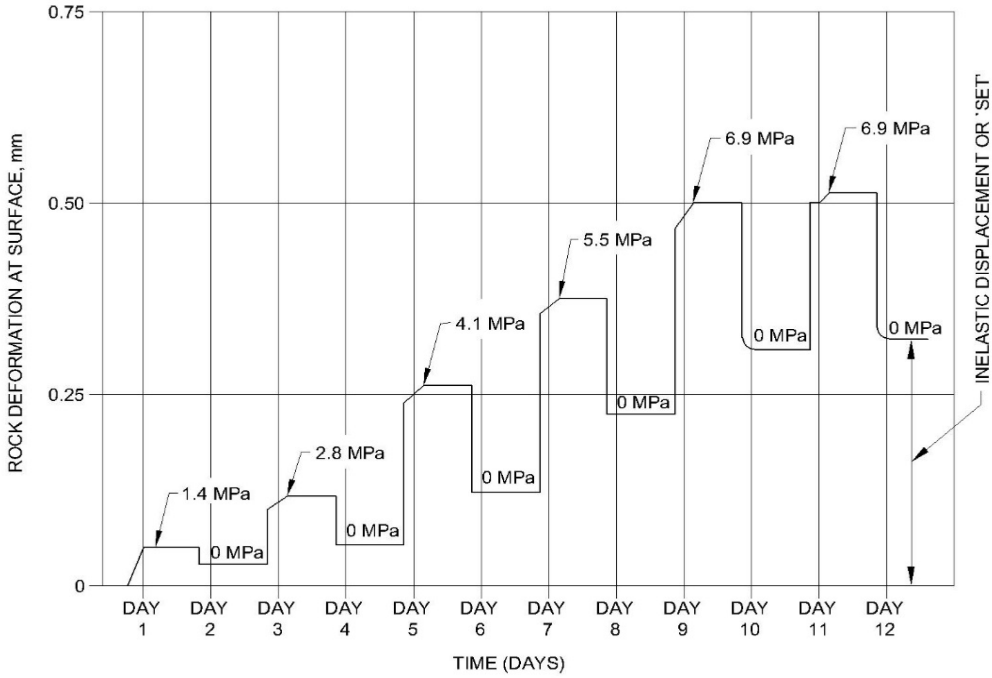


FIG. 7 ROCK DEFORMATION AT SURFACE *VERSUS* TIME — UNIAXIAL JACKING TEST

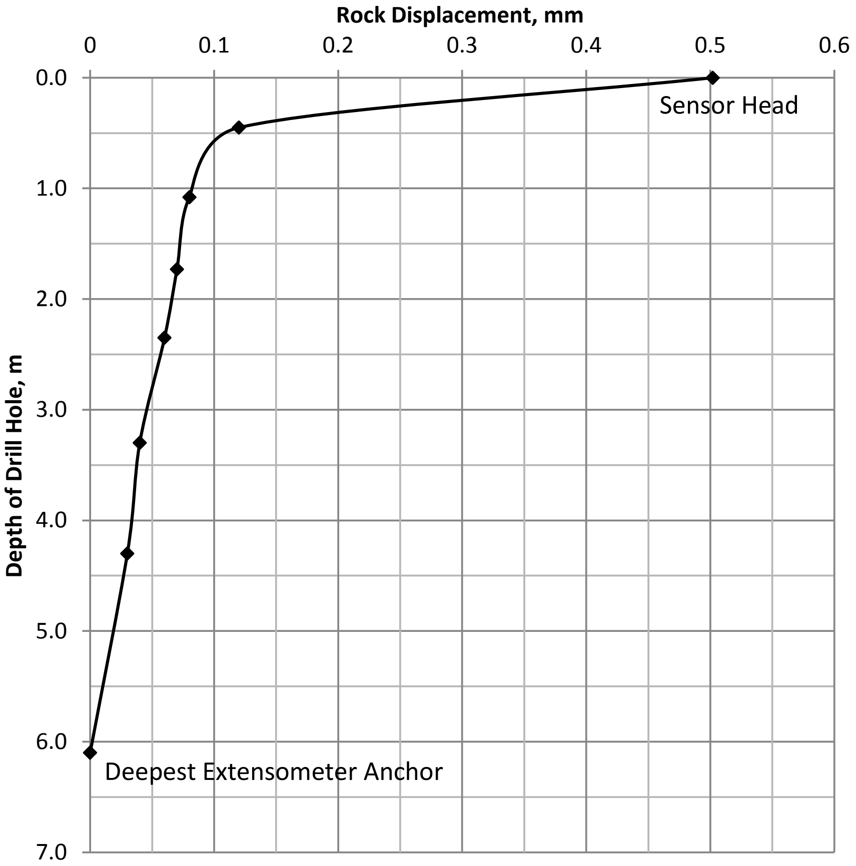


FIG. 8 ROCK DEFORMATION *VERSUS* DEPTH-UNIAXIAL JACKING TEST WITH BOREHOLE EXTENSOMETERS

5.9 The creep test as shown in Fig. 7 is essential for weak/soft rocks.

5.10 The test duration mentioned in **5.3** and **5.5** are for creep tests. The dial gauge or LVDT reading at each increment can be taken when the deformations are stable. Generally, 2 min per increment are adequate. Maintain peak and zero (seating) pressure for 10 min for normal deformability test.

6 INTERPRETATION OF THE TEST DATA

6.1 Because rock mass is not truly an elastic material, there is considerable latitude available in selecting the type of modulus to be computed for the design purpose. All moduli are computed from elastic solution for rigid plate on semi-infinite homogeneous, isotropic and elastic medium, the only difference is the portion of the curve used by the designer to obtain the deformation and stress changes. In the cyclic loading tests, it is usually found that large deformation occur in the first loading cycle while the recovery of the strain on removal of the load is comparatively very small indicating a permanent set in the rock mass by closing of cracks and joints. The deformations in the 2nd, 3rd, 4th and 5th cycles of loading are used for calculating the deformation moduli at different stress levels. Similarly, the recovery in the 2nd, 3rd, 4th and 5th cycles of unloading arc used for calculating the elastic moduli at the corresponding stress levels. For reporting the average deformation modulus and the elastic modulus, the values corresponding to the last cycle may be considered.

6.2 The purpose of the uniaxial jacking test is to determine the extent to which the rock mass shall deform under externally applied loads. Care is thus needed in the interpretation of the results of the tests so that the settlement of the structure is correctly estimated. Computations for the determination of modulus of deformation should include all deformations due to applied loads whether elastic or plastic and the creep effect and exclude any deformation on account of blast damage, surface preparation or any other loosening effect which is assumed equal to deformation in the first cycle resulting in consolidation of disturbed zone of rock mass.

6.3 The effect of creep shall be taken care of while computing the deformation modulus.

6.4 The evaluation of deformation modulus is based on rigid die-pressed into semi-infinite elastic medium.

The modulus of deformation corresponding to test set up described in **4.3** and **4.4**, for each cycle shall be calculated from the following formula:

$$E_{\mathrm{d}} = \frac{P\left(1-\nu^2\right)}{2\delta R}$$

where

E_{d} = modulus of deformation;

ν = Poisson's ratio of the rock from the laboratory tests on representative rock. If its value has not been determined in the lab, it may be considered between 0.20 and 0.30. Its value for different rock types shall be assumed as 0.20 for excellent rocks such as granite, etc, 0.25 for gneiss, quartzites, etc. and 0.30 for mica schist, slates, etc;

δ = deformation of the test slate in one loading cycle (δ_{d} Ref. Fig. 6);

P = total load on the test plate; and

R = radius of test plate.

Similarly, unloading modulus from unloading curve shall be calculated for each cycle using the above equation by taking **δ** equal to recoverable deformation (δ_{r} *see* Fig. 6) of that cycle. Which is also called as elastic modulus (E_{e}).

6.5 For the test set up described in **4.5**, the displacement at and point beneath the centre of a circular loaded area is expressed as follows:

$$\delta = \frac{2p\left(1-\nu^2\right)}{E_{\mathrm{d}}}\left[\sqrt{R^2+Z^2}-Z\right]-\frac{pZ\left(1+\nu\right)}{E_{\mathrm{d}}}\left[\frac{Z}{\sqrt{R^2+Z^2}}-1\right]$$

where

δ = displacement in the direction of loading in one cycle;

Z = distance from loaded surface to the point where displacement is measured;

p = stress at loaded surface;

R = radius of loaded area;

ν = Poisson's ratio of the rock; and

E_{d} = deformation modulus of rock mass.

At the loaded surface, where value of 'Z' is zero, the above equation may be rewritten as:

$$E_{\mathrm{d}} = 2pR\left(1-\nu^2\right)/\delta$$

But in the test set up in question, if the load shall be applied through a circular flat jack with a hole in the centre and therefore considering R_1 as inner radius and R_2 as outer radius of the flat jack the displacement expression becomes as:

$$\delta = \frac{2p\left(1-\nu^2\right)}{E_{\mathrm{d}}}\left[\sqrt{R_2^2+Z^2}-\sqrt{R_1^2+Z^2}\right]+$$

$$\frac{pZ^2\left(1+\nu\right)}{E_{\mathrm{d}}}\left[\frac{1}{\sqrt{R_1^2+Z^2}}-\frac{1}{\sqrt{R_2^2+Z^2}}\right]$$

By putting the values of R_1, R_2 and Z, the displacement at a particular point '1' or '2' may be expressed as:

$$\delta_1 = p(K_1)/E_\mathrm{d} \text{ or } \delta_2 = p(K_2)/E_\mathrm{d}$$

Therefore, the modulus of deformation of the rock mass in the zone between depth Z_1 and Z_2 may be determined from the following equation:

$$E_\mathrm{d} = p(K_1 - K_2)/(\delta_1 - \delta_2)$$

6.6 Besides, creep factor shall also be calculated for each cycle by the following expression (*see* Fig. 6):

Change in deformation at constant load (percent) =

$$\frac{\text{Creep of Cycle}}{\text{Deformation During Load Increase}} \times 100$$

7 REPORTING OF THE RESULTS

In addition to the information in **2.5**, the report of the test should also include the following:

a) Whether the test was conducted in a drift or on a rock surface in open;
b) Location of the test site indicating three dimensional coordinates, drift number, chain age, etc;
c) Extent of rock/loose burden above the test site;
d) Whether the test was conducted on floor, or on roof or on side walls;
e) Period elapsed between excavation of the site and testing;
f) Direction of testing, that is, whether vertical, horizontal or inclined;
g) Orientation of the rock mass stratification and the direction of loading during testing;
h) A complete geological description of the rock mass with RMR and Q;
j) *In-situ* stresses in the rock mass;
k) Name of the testing agency;
m) A description of the uniaxial apparatus including the photos of the installed equipment, specifications, accuracy, sensitivity of all the pressure and deformation instruments;
n) Tabulation of the observed data;
p) Plots of stress *Versus* deformation, time *Versus* deformation and depth *Versus* deformation;
q) Deformation and clastic moduli at different stresses levels;
r) Creep factors at different stress levels;
s) Any other relevant information; and
t) A plot between $E_\mathrm{d} / E_\mathrm{r}$ and RMR will help in selecting design deformation modulus.

8 APPLICATION OF MODULUS OF DEFORMATION

The designer should be careful in application of *in-situ* moduli of rock mass on the following points:

a) Modulus of deformation (E_d) for static analysis of foundation of dams, etc, corresponding to various stress levels in the rock foundation;
b) Dynamic modulus for dynamic analysis of dams, etc, which may be taken equal to elastic modulus (E_e) corresponding to the maximum stress level of the test. This is recommended because dynamic deformation will be simulated more realistically by E_e, than by E_d;
c) Elastic modulus (E_e) for design of concrete lining in pressure tunnels and pen-stocks, etc, because internal water pressure leads to reduction of deviatoric stresses within the rock mass;
d) In practice, the *in-situ* rock mass lies under confining pressure due to depth, but the deformation modulus is measured with almost no confining pressure. Besides, in drifts the tests are performed in elastoplastic zone near the surface of the rock mass. Thus, in poor rock masses the increase in modulus of deformation with confining pressure and depth below ground surface becomes important and pronounced. However, it leads to a conservative design if borehole extensometers are not used; and
e) In river valley projects, rock mass gets saturated in some areas after charging water conductor system/after filling of reservoir. The modulus of deformation and elastic modulus are reduced drastically specially in poor rocks with water sensitive minerals. Thus these moduli should be multiplied by suitable correction factors for saturation where tests are not done on saturated rock masses.

NOTES

1 The settlement of foundation of high dams especially in narrow valleys should be analysed by the 3-D finite element method (two dimensional analysis is found to give very conservative and unrealistic results).

2 If the behaviour of the rock mass is plastic, non-linear should be performed.

9 SAFETY ASPECTS DURING TESTING

The following safety precautions should be observed during testing:

a) Pressure lines should be free from air in order to avoid bursting of lines.
b) Watch out carefully for failure of rock mass in punching shear at both ends. This may lead to collapse of assembly.
c) Reaction pad from roof may get loose and fall while unloading as well as dismantling the equipment setup.

d) Total deformation should not exceed deformation capabilities of flat jacks, normally this is approximately 3 percent of the diameter.

e) Hydraulic jack should be used within the prescribed pressure and plunger range.

f) The assembly should be checked for proper orientation throughout the testing work.

g) All the persons working inside drift during site preparation and testing shall wear personal safety equipment like helmets, gumboot and torch light.

h) The testing site should have proper lighting and dewatering arrangements

ANNEX A

(*Foreword*)

COMMITTEE COMPOSITION

Rock Mechanics Sectional Committee, CED 48

Organization	*Representative(s)*
Indian Institute of Technology Roorkee, Roorkee	Dr N. K. Samadhiya (***Chairman***)
AIMIL Ltd, New Delhi	Shri Sharique Khan Shri Akhil Raj (*Alternate*)
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(*Continued from second cover*)

This second revision of the standard incorporates modifications found necessary as a result of the experience gained with the use of the standard and to bring the standard in line with present good practices being followed in the country and abroad. The principal modifications in this revision are as follows:

a) As this test is being used for evaluation of modulus of deformation of rock mass, the title of the code has been suitably amended by using the words ‘rock mass’ instead of ‘rock’.
b) The test setup for uniaxial jacking test in vertical direction with stiff plate (*see* Fig. 2) has been improved.
c) The test setup in open area/trench has been included.
d) In the interpretation of test data, as compared to the Bouzinesq’s equation for a point load on infinite homogeneous isotropic and linearly elastic material in the last version, the evaluation of deformation modulus has been amended based on rigid die-pressed into semi-infinite elastic medium.
e) Safety aspects to be followed during testing have also been included.

In the formulation of this standard, due weightage has been given to international coordination among the standards and practices in different countries in addition to relating it to the practices in the field in this country.

The composition of the Committee responsible for the formulation of this standard is given in Annex A

In reporting the result of a test or analysts, made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Headquarters:

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Regional Offices: *Telephones*

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg
NEW DELHI 110002 — 2323 7617, 2323 3841

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